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EMBEDDEDNESS OF SALMONID HABITAT OF SELECTED STREAMS ON THE PAYETTE NATIONAL FOREST 1987-1988

by
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PAYETTE NATIONAL FOREST

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INTRODUCTION

Comparison of fish habitat condition among various locations within the Payette National Forest is necessary in order to evaluate past and present activities and to facilitate development of future management objectives for aquatic ecosystems. The single most significant element of fish habitat management during recent history has been development of objectives for limiting deposition of fine sediment. Four environmental impact statements within Forest during the past 12 years (Anon., 1977; Anon., 1979; Anon., 1981; Anon., 1988) have all dealt with the impact of sediment on fish habitat as a major issue. The Payette National Forest Land and Resource Management Plan outlines an expanded habitat monitoring effort, especially in the South Fork Salmon River drainage which has been identified as an area of special concern.

Embeddedness has been used as an indicator of salmonid habitat quality on Payette National Forest since 1983 (see Burns, 1984). Embeddedness is generically defined as the amount of fine sediment which is deposited in the interstices between larger stream substrate particles. This fish habitat characteristic has been demonstrated by research (Klamt, 1976; Kelly and Dettman, 1980) to negatively influence the ability of a stream to rear fish. Increasing the amount of deposition, embeddedness, decreases the number of fish a stream can rear.

Stowell, Espinosa, Bjornn, Platts, Burns and Irving(1984) related increased embeddedness to man-caused sedimentation, as did Burns(1984) and Burns and Edwards(1985) for the Payette National Forest.

This inventory of embeddedness of fish habitat was conducted during 1987 and 1988, in order to empirically answer several questions.

1) Are there detectable sources of man-caused sediment, which could be detrimental to fish habitat, associated with the Thunder Mountain mining area?

2) Are there detectable sources of man-caused sediment, which could be detrimental to fish habitat, associated with the Stibnite mining area?

3) What is the condition of the mainstem South Fork Salmon River and its tributaries? This granitic watershed has been described by various authors (Anon., 1969; Anon., 1970; Knight, Thompson, Kulesza and Dean, 1974; Thompson, Skabelund and Kulesza, 1973).

4) Are there any noticeable time trends in cobble embeddedness?

5) What is the relationship between free matrix measurements and embeddedness measurements; is there any advantage of one method over the other?

6) Are there some simple watershed or stream characteristics that influence embeddedness measurements, independent of sediment input? Quantification of these factors may help to resolve some of the variability that hinders interpretation of monitoring data.

STUDY AREA

Sampling locations are found in watersheds of three different geologic formations which have distinct soil characteristics. Most of tributaries are located in the Idaho Batholith, which is characterized by coarse, granitic soils that are prone to erosion. Other tributaries are found either in the Yellow Jacket Formation, or in the Challis Volcanic formation. Soils in these formations tend to be more stable.

Thunder Mountain Mining Area

Eight locations were established in the Monumental Creek drainage to determine the background level of fine sediment, and the upstream and downstream extent of measurable increases in sediment deposition related to mining activities in the Thunder Mountain area (Table 1). These were in the same areas as those sampled by Burns(1987), and Burns and Edwards(1985). Control areas for Monumental Creek included Snowslide Creek, the West Fork of Monumental Creek, and Monumental Creek downstream from Annie Creek. Sites above and below Mule Creek are used to quantify the amount of mining effluent that enters Monumental Creek from Mule Creek.

Stibnite Mining Area

Seven locations were identified surrounding the Stibnite mining area (Table 2). These were in the same areas as those sampled by Burns (1987) in 1986, Burns (1984) in 1983, and Burns and Edwards (1985) in 1984. Two locations in Profile and Quartz Creeks were added in 1988. Control areas were located in Tamarack Creek, and Sugar Creek upstream of the mine in West End Creek. Three locations were sampled to determine the downstream extent of possible sediment deposition resulting from the West End mine.

South Fork Salmon River Drainage

Twelve locations were identified in the mainstem South Fork Salmon River and its tributaries (Table 3). These locations were selected in an attempt to determine the extent of any changes from conditions described by Burns(1987 and 1984), and Burns and Edwards(1985). The mainstem South Fork was sampled at the Glory Hole. Two major tributaries, the lower Secesh River and East Fork were sampled. Smaller tributaries called "developed" by Burns(1984) were sampled, including Cow, Buckhorn, Fitsum and Zena Creeks. Lick Creek, called "partially developed" by Burns(1984), was sampled. Tributaries called "undeveloped" by Burns(1984) were sampled, including Blackmare, Fourmile Creeks.

TABLE 1. **Location of Embeddedness Samples from the Thunder Mountain Mining Area.** Samples were taken from Monumental Creek in locations were picked to surround mining activity on Thunder Mountain. Samples above and below Mule Creek in Monumental Creek were sampled by Burns (1987), and Burns and Edwards (1985). Legal descriptions are approximate.

Location	Township	Section	Range	Description
Snowslide Creek	20N	6	11E	Pool tailout 10m upstream from Monumental Creek.
Monumental Creek downstream from Holy Terror Creek	20N	33	11E	About 400m downstream from the mouth of Holy Terror Creek at trail crossing.
Monumental Creek downstream from the West Fork of Monumental Creek	19N	5NE1/4	11E	About 400m downstream from the West Fork at trail crossing
West Fork of Monumental Creek	19N	8NW1/4	11E	Pool tailout about 100m upstream from Monumental Creek, at trail crossing.
Monumental Creek downstream from Mule Creek	19N	24NE1/4	10E	Pool tailout sampled 200m downstream from Mule Creek
Monumental Creek upstream from Mule Creek	19N	24NE1/4	10E	About 100m upstream from Mule Creek.
Monumental Creek downstream from Coon Creek	19N	25	10E	Pool tailout downstream from Coon Creek.
Monumental Creek downstream from Annie Creek	18N	10NE1/4	10E	100m downstream from Annie Creek.

Table 2. **Location of Embeddedness Samples from the Stibnite Mining Area.** Embeddedness samples were taken from the East Fork South Fork Salmon River (EF) vicinity. These locations were picked to "bracket" sediment input from an active open-pit mine near Stibnite, Idaho, in West End Creek (WE), and were sampled by Burns (1987 and 1984), and Burns and Edwards (1985). Two locations in Profile and Quartz Creeks were added in 1988. Legal descriptions are approximate.

Location	Township	Section	Range	Description
EF downstream from Sugar Creek	19N	34	9E	Pool tailout in EF 200m downstream from Sugar Creek.
EF upstream from Vibika Creek	19N	27NW1/4	8E	In EF 10m upstream from Vibika Creek.
Sugar Creek downstream from WE	19N	34SE1/4	9E	In Sugar Creek upstream for FS road 48 bridge.
Sugar Creek upstream from WE	19N	35SE1/4	9E	In Sugar Creek 30m upstream from WE.
Tamarack Creek	19N	29NW1/4	9E	In Tamarack Creek upstream from FS road 48 bridge.
Profile Creek	19N	25NW1/4	8E	In Profile Creek 100m upstream FS Road 48 bridge.
Quartz Creek	19N	21NE1/4	8E	In Quartz Creek 200m upstream from EF.

Table 3. **Location of Embeddedness Samples from the South Fork Salmon River.** Sampling locations in the mainstem South Fork Salmon River and tributaries were selected in order to determine their relative condition. Some areas sampled by Burns (1987 and 1984), and Burns and Edwards (1985) were selected for comparison. Legal descriptions are approximate.

Location	Township	Section	Range	Description
Blackmare Creek	17N	10SE1/4	6E	Downstream from old road crossing.
Buckhorn Creek	18N	4SW1/4	6E	20m upstream from South Fork.
Cow Creek	20N	19NE1/4	6E	100m upstream from mouth.
Fitsum Creek	19N	9NE1/4	6E	100m upstream from mouth.
Fourmile Creek	18N	26NW1/4	6E	Upstream from FS road 674 culvert.
Glory Hole Area	19N	16NE1/4	6E	In South Fork in a run 100m downstream from Glory Hole.
Lick Creek	20N	18SE1/4	6E	Vicinity of old bridge.
Lower East Fork	19N	30NW1/4	7E	Pool tailout at base of avalanche path 3.7km upstream from Forest highway 48 bridge.
Secesh River downstream from Zena Creek	20N	33NE1/4	6E	Pool tailout at dispersed camp site 2km downstream from Forest highway 48 bridge.
Zena Creek	20N	28NW1/4	6E	20m upstream from reservoir highwater.
Grouse Creek	23N	3NW1/4	5E	100m below culvert on road to Golden Rule Mine.
Three Mile Creek	23N	26NE1/4	4E	Immediately upstream from the turn off to meadow where road 246 crosses the stream.

METHODS

Embeddedness Measurements

Methods for this inventory were adapted from Kelly and Dettman (1980),Burns (1984) and Burns and Edwards (1985). Data acquired could be entered into the General Aquatic Wildlife System (GAWS) of Region Four of the USDA-FS.

Embeddedness was earlier defined in generic terminology. For the remainder of this report embeddedness refers specifically to the proportion of a matrix particle (4.5 - 30.0 cm greatest diameter) surrounded by fine sediment (< 6.3 mm dia.) as described by Burns and Edwards (1985). A population of single matrix particles must be sampled in order to characterize fish habitat conditions in a quantitatively precise manner.

The standard of measurement was established as the closest millimeter. A sample size of 100 was selected as a minimum number of measurements for each population or location sampled. These standards were developed based on Burns'(1984) work and Burns and Edwards(1985). Tools used were those described by Burns and Edwards (1985).

Field techniques were those described by Burns and Edwards (1985). As a point of clarification all locations are pool tailouts, but the form varies from conditions similar to those described variously as runs or pocket water pools. A key similarity of all locations is that the area sampled was as central in the flow as possible in the transition out of a pool to the next downstream feature. Peripheral stream areas, point bars and negative velocity areas were rejected as sampling areas as described in Burns (1984). In small streams this leads to almost totally stratified sampling rather stratified random sampling.

Samples were taken systematically at each location in order to minimize the number of variables influencing measurement. Fish habitat was defined consistently among locations which would later be compared. All locations were sampled during low flow conditions from mid-July through September. Criteria used to define fish habitat were developed from Bovee (1978) and further refined for this study and are defined in Burns and Edwards (1985).

Free Matrix Measurements

Free matrix particles are rocks which are not surrounded by fine sediment. Previous works by Burns (1984), Munther and Frank (1986, 1986a, & 1986b), Munther and Lilburn (1987), Potyondy (1988), and Torquemada and Platts (1988) indicate a direct relationship between mean embeddedness and the proportion of free matrix particles.

Free matrix samples were taken in the same reach as the embeddedness samples. Locations were chosen by "randomly" tossing a 60cm diameter hoop (the same used in embeddedness samples) behind the back, and working upstream. Thirty hoops (replicates) were sampled at each site. Sample locations were rejected if the following criteria were not met:

1. Water depth must be greater than 0 cm and less than 45 cm.
2. If all particles were greater than 30 cm ~~and/or less than 4.5 cm~~.

These criteria are much less restrictive than the criteria for embeddedness measurements. Criteria regarding features such as riffle, run, or pool tailout were not used.

All rocks that were exposed to the surface, and between 4.5 and 30 cm in diameter were tallied in each hoop as being free or embedded. To avoid counting the same rock more than once, counting was implemented by beginning on the downstream side of the hoop and counting across the hoop toward the upstream side while keeping one hand on the last rock counted. Water depth and float time across the hoop diameter were recorded at each sampling location.

Statistical Analysis

Free matrix and embeddedness measurements from 1988 were analyzed by the CLUSTER procedure in SPSS-X. This procedure is an agglomerative technique which groups data in a heirarchical fashion by computing the proximities between the initial site data, and combining the two nearest sites (or clusters) to form a new cluster. This process repeats until all sites have been combined into one cluster. The output shows the hierarchy of clusters from a single cluster to as many clusters as there are cases. Within each hierarchical level, each site belongs to only cluster.

The clustering method used in the analysis is the average linkage method, and the proximity measure is Euclidian distance. The dendrogram produced in the output is scaled by the distance where the clusters combine, and represents the relative degree of association or difference between sites. This method was chosen over parametric techniques since it retains much more information about the relationship between groups, and there are few assumptions concerning the distribution of the data.

RESULTS

Data were divided into three groups for analysis. Those groups were the Thunder Mountain mining area, the Stibnite mining area, and the South Fork Salmon River drainage.

Thunder Mountain Mining Area

Mean embeddedness ranged from a low of 7% in Monumental Creek upstream from Mule Creek, immediately downstream from Roosevelt Lake in 1987, to a high of 40% in Monumental Creek downstream from Mule Creek in 1987 (Table 4). Means in the remainder of the area were all 30% or less.

Control sites did not differ appreciably from the other sites, except for a large difference between the Monumental Creek site above and the site below Mule Creek. Embeddedness ranged from 7 to 11% above Mule Creek, and ranged from 27 to 40% below.

Stibnite Mining Area

Mean embeddedness in the Stibnite area ranged from a low of 12% in Tamarack Creek in 1987 to a high of 49% in the East Fork downstream from Sugar Creek in 1987 (Table 5). Embeddedness was generally higher in 1988 than in 1987.

South Fork Salmon River Drainage

Mean embeddedness ranged from a low of 28% in Lick Creek in 1988 to a high of 50% in Blackmare Creek in 1988 (Table 6). Embeddedness measurements were high overall. Only four out of twelve locations had sample means less than 40%. They included Cow Creek, Fourmile Creek, Lower East Fork, and Lick Creek.

Free matrix particles ranged from 7% in Buckhorn Creek to 51% in Lower East Fork (Table 6). Free matrix measurements were similar to embeddedness measurements, although the relative ratings differ.

A linear regression analysis was performed with the mean value of free matrix particles tallied in 30 hoops, and mean embeddedness (Figure 1). These measurements are from different data sets collected in the same reach. The correlation coefficient was 0.66, and the slope 0.485.

Table 4. **Mean Embeddedness and Mean Free Matrix Measurements in the Thunder Mountain Area; 1987 & 1988.** Embeddedness ranged from a low of 7% in Monumental Creek immediately upstream from Mule Creek in 1987, to a high of 40% immediately downstream of Mule Creek in 1987. The number of samples (n) is equal to the number of matrix particles measured and the confidence interval is about the mean.

LOCATION	YEAR	FREE MATRIX	95% CONFIDENCE INTERVAL	MEAN EMBEDDEDNESS	n	95% CONFIDENCE INTERVAL
Snowslide Creek	1988			18	102	12 - 23
Monumental Creek downstream from Holy Terror Creek	1987			14	103	9 - 19
Monumental Creek downstream from the West Fork of Monumental Creek	1987			13	104	9 - 18
West Fork of Monumental Creek	1987			15	102	10 - 20
	1988	39	31 - 48	21	104	16 - 27
Monumental Creek downstream from Mule Creek	1987			40	108	35 - 44
	1988	24	19 - 30	23	116	18 - 28
Monumental Creek upstream from Mule Creek	1987			7	101	3 - 11
	1988	79	72 - 85	11	123	7 - 15
Monumental Creek downstream from Coon Creek	1987			27	121	22 - 32
Monumental Creek downstream from Annie Creek	1987			30	118	25 - 35

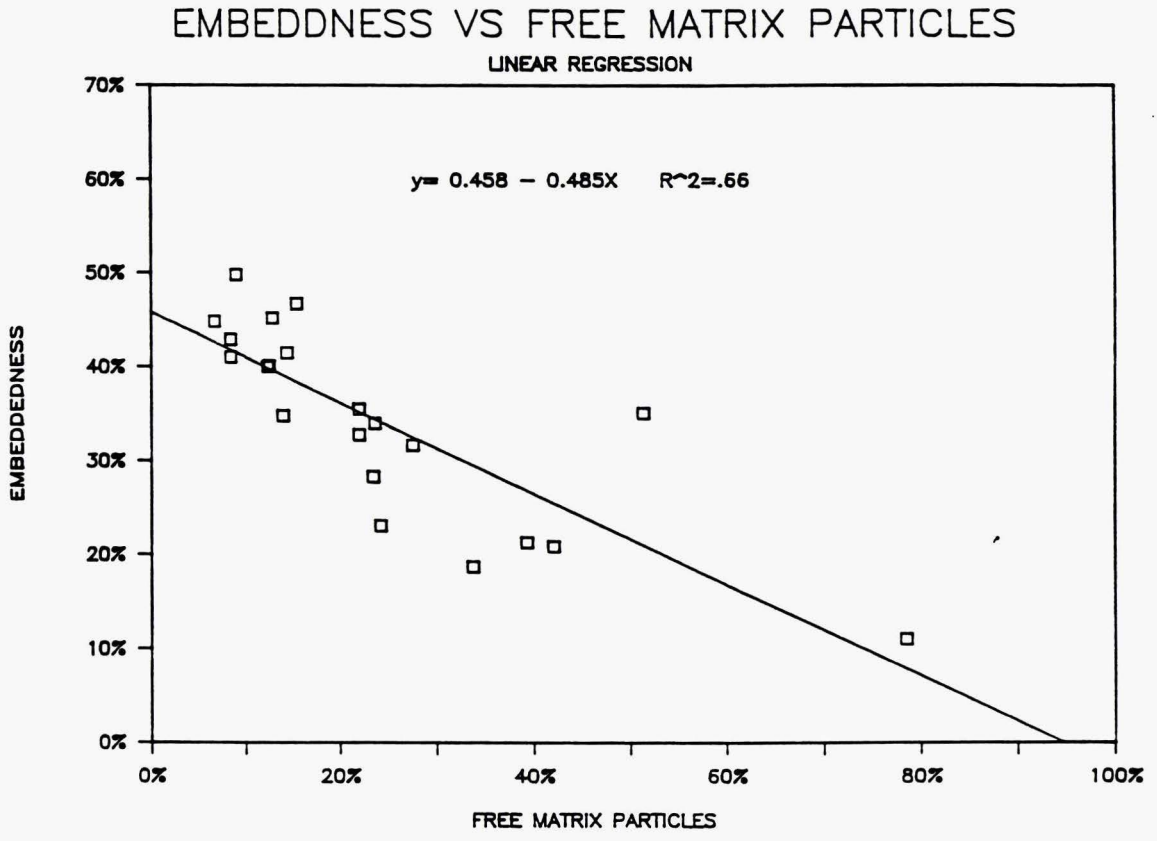
Table 5. **Mean Embeddedness and Free Matrix Measurements in the Stibnite Mining Area; 1987 & 1988.** Embeddedness ranged from 12% in Tamarack Creek in 1987 to 49% in the East Fork downstream from Sugar Creek in 1987. The number of samples (n) is equal to the number of matrix particles measured and the confidence interval is about the mean.

LOCATION	YEAR	FREE MATRIX	95% CONFIDENCE INTERVAL	MEAN EMBEDDEDNESS	n	95% CONFIDENCE INTERVAL
East Fork downstream from Sugar Creek	1987			49	108	44 - 55
East Fork upstream from Vibika Creek	1987			20	102	14 - 25
	1988	51	41 - 62	34	129	30 - 38
Sugar Creek downstream from West End Creek	1987			32	112	27 - 37
	1988	22	28 - 26	33	117	28 - 38
Sugar Creek upstream from West End Creek	1987			27	102	21 - 32
	1988	13	10 - 16	45	101	39 - 51
Tamarack Creek	1987			12	102	7 - 17
	1988	34	29 - 39	19	100	14 - 24
Profile Creek	1988	28	22 - 33	32	101	26 - 37
Quartz Creek	1988	42	36 - 49	21	109	16 - 26

Table 6. **Mean Embeddedness and Mean Free Matrix Measurements in the South Fork Salmon River Drainage in 1988.** High values (*) and low values (**) are indicated below. The number of embeddedness samples (n) is equal to the number of matrix particles measured and the number of free matrix samples is 30 hoops for all locations. The confidence iterval is about the mean.

LOCATION	FREE MATRIX	95% CONFIDENCE INTERVAL	MEAN EMBEDDEDNESS	n	95% CONFIDENCE INTERVAL
Blackmare Creek	9	6 - 10	50*	105	45 - 54
Buckhorn Creek	7**	17 - 27	45	103	40 - 49
Cow Creek	14	9 - 19	35	107	31 - 39
Fitsum Creek	13	8 - 17	40	100	36 - 44
Fourmile Creek	22	27 - 27	36	112	31 - 40
Grouse Creek	14	13 - 16	42	103	37 - 46
Lick Creek	24	17 - 30	28**	108	24 - 32
Lower East Fork	51*	41 - 62	35	114	30 - 40
Three Mile Creek	8	6 - 10	41	115	36 - 46
Glory Hole area	12	9 - 16	40	107	36 - 45
Secesh River downstream from Zena Creek	8	5 - 11	43	101	38 - 48
Zena Creek	16	11 - 21	47	101	42 - 51

Figure 1. **Relationship of Embeddedness and Free Matrix Measurements.** Data were collected by both techniques for each location in 1988. Both measurements were made in the same general area in each stream.



DISCUSSION

There were no large changes in embeddedness in 1987 or 1988. With the exception of a few locations, the overall trend was a slight increase in embeddedness, but within the the range of usual variation. Below average precipitation in 1988 may have produced insufficient flows for flushing the sediment.

Thunder Mountain Mining Area

Embeddedness measurements for several locations in the Thunder Mountain Area from 1983 to 1988 demonstrate no obvious trends in control locations, but an apparent improving trend in the location affected by Mule Creek (Table 7). The site at Monumental Creek upstream from Mule Creek lies immediately downstream from Roosevelt Lake which acts as a sediment trap. Embeddedness is very low in comparison with other sites in the vicinity. West Fork Monumental Creek is an undisturbed control area, and Monumental Creek below Mule Creek is influenced by mining effluent from Mule Creek. This site generally had the highest amount of embeddedness.

Considerable year-to-year variation exists for all sites (Figure 2), but is particularly notable for Monumental Creek above Mule Creek, below Roosevelt Lake. Since Roosevelt Lake traps most of the sediment, changes in embeddedness may largely be attributed to variation in the flushing and deposition of sediment. At this site, natural variation may account for a change in embeddedness of 10%, or a proportional change in fine sediments of more than 100% in any given year.

Mule Creek effluents continue to degrade habitat in Monumental Creek, but flushes in 1986 and in 1988 have reduced fine sediments in Monumental Creek. In spite of year-to-year fluctuations, the overall downward slope for Monumental Creek below Mule Creek (Figure 2) indicates an improving trend.

Stibnite Mining Area

Embeddedness trends in the Stibnite area are similar to those for Thunder Mountain (Table 7). Tamarack Creek is an undisturbed control and consistently has a low embeddedness of around 15%. Sugar Creek above West End Creek is the upstream control for the West End Mine. The other two sites are are downstream from the West End Mine, and generally show a higher amount of embeddedness than the controls.

Embeddedness trends in Sugar Creek above and below the mine demonstrate differences among the locations (Figure 3). Sugar Creek below West End showed an improving trend between 1983 and 1986, but has returned to the same embeddedness level as 1985. All three sites exhibited a sharp increase in embeddedness in 1988, possibly due to insufficient flows for flushing.

South Fork Salmon River Drainage

No distinct changes were noted in the South Fork Drainage in 1988 (Table 8). Most of the sites were found to have moderate to high embeddedness, but there was no pattern in the changes that could be

Table 7. **Embeddedness Trends in the Stibnite and Thunder Mountain Mining Areas.**

LOCATION	1983	1984	1985	1986	1987	1988
Thunder Mountain Area						
West Fork of Monumental Creek	-	24	15	21	15	21
Monumental Creek downstream from Mule Creek	45	51	44	19	40	23
Monumental Creek upstream from Mule Creek	15	5	7	10	7	11
Stibnite Area						
East Fork downstream from Sugar Creek	42	31	34	30	49	34
Sugar Creek downstream from West End Creek	50	48	44	30	32	45
Sugar Creek upstream from West End Creek	30	26	27	36	27	33
Tamarack Creek	14	16	18	14	12	19

Figure 2. **Embeddedness Trends in the Thunder Mountain Area, 1983 to 1988.** The graph indicates an improving trend for the sampling locations in Monumental Creek. The Monumental Creek site below Mule Creek is influenced by mining activity, and the other two sites are controls.

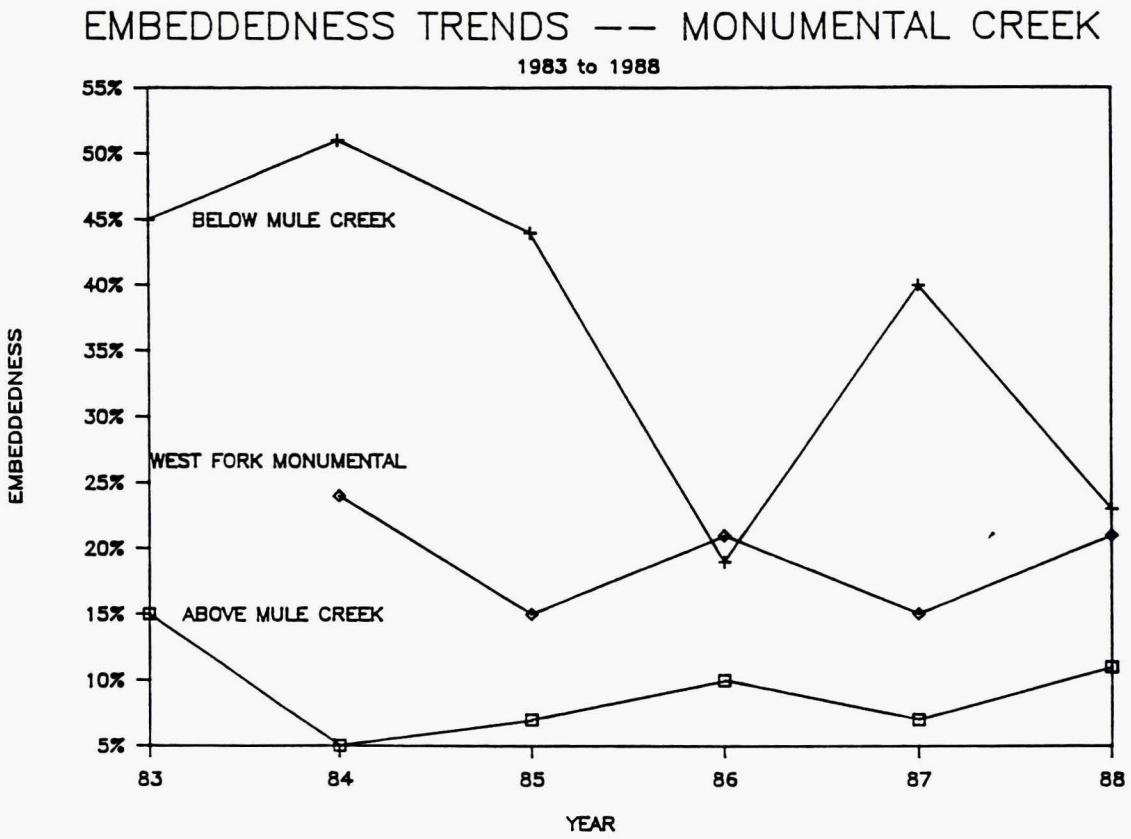


Figure 3. **Embeddedness Trends in the Stibnite Mining Area, 1983 to 1988.** The graph shows an improving trend for the sampling location in Sugar Creek from 1983 to 1987, with a large change in 1988. More data is needed to interpret this change. The Sugar Creek site below West End Creek is influenced by West End Mine, and the other two sites are controls.

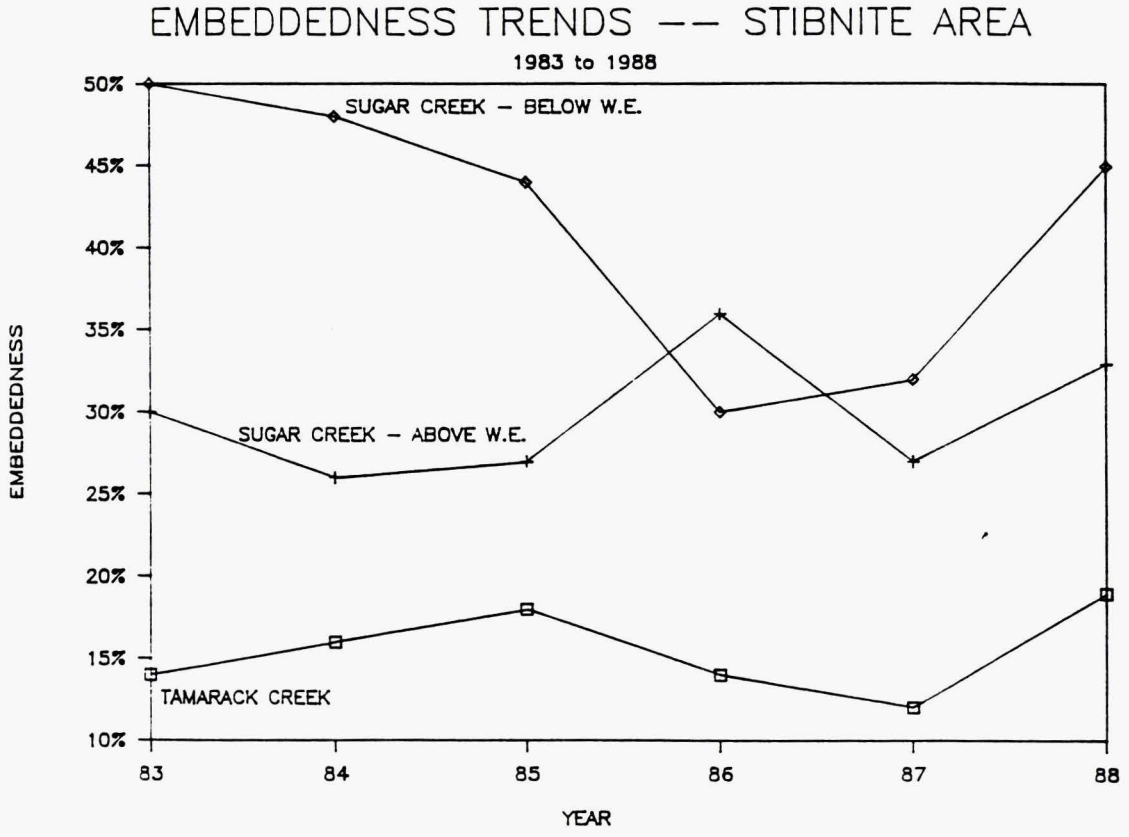


Table 8. **Embeddedness trends in the South Fork Drainage.**

LOCATION	1983	1984	1986	1988
Buckhorn Creek	41		34	41
Cow Creek	50		50	35
Fitsum Creek	43		25	40
Zena Creek	48		32	47
Lick Creek	19		19	28
Blackmare Creek	21	20	32	50
Fourmile Creek	19		17	36
Glory Hole area		63	58	40
Lower East Fork		29	34	35
Secesh below Zena		39	39	43

attributed to any specific factor. There was an increase in embeddedness in all locations except for Cow Creek and Glory Hole, since 1986 when the South Fork was last sampled. Eight of twelve sites had 40% or more embeddedness. Overall, the habitat condition has not changed from the previous 5 years of monitoring.

Free matrix measurements taken at the same locations as the embeddedness measurements reflected the same general values as embeddedness. The relationship between percent free particles and embeddedness in 1988 is nearly identical to the findings in 1983 by Burns (1984) for the same drainages. The regression equation in 1988 is E = 45.8 - 0.49M, compared to E = 44.56 - 0.5M in 1983, where E is embeddedness and M is the percentage of free matrix particles. Other investigators (King 1988, Munther and Frank 1986, 1986a, 1986b, Potyondy 1988, and Torquemada and Platts 1988) have all found a similar relationship in a variety of drainages. Based on these findings, there appears to be a consistent relationship with a regression of approximately E = 50 - 0.5M.

Although the proportion of free matrix particles in a sample area may be a good estimator of embeddedness or useful as an index of salmonid habitat quality, it is a time-consuming method. One of the reasons for examining this method was to see if it might reduce sampling time while measuring the same parameters as embeddedness. For these locations, the free matrix method took more than twice the time necessary to measure embeddedness. Whereas approximately 100 rocks are measured using embeddedness, usually 400 to 600 rocks were counted to obtain free matrix measurements. Additionally, 90 float time measurements and 30 depth measurements were recorded at each location for the free matrix method, compared to approximately 9 float and 3 depth measurements for embeddedness. Embeddedness samples are preferable to free matrix measurements when time is a consideration.

Relationship of Emdeddedness to Stream and Watershed Features

Stream order, depth and velocity, and geology are stream and watershed features which might influence the levels of fine sediment found in a particular location (Table 9). These characteristics were examined to determine if they had a noticable effect on embeddedness. Three primary geologies were sampled in similar stream order and hydraulic conditions.

Cluster analysis was used to uncover certain factors which broadly influence embeddedness measurements. Two separate analyses were performed; clustering sites by embeddedness and free matrix measurements (Figure 4); and clustering sites by embeddedness, free matrix particles, and stream order (Figure 5). Both analyses yielded similar results. Sites toward the top of the page generally are the most embedded, with the least embedded sites near the bottom.

The most striking result of the analysis is seen at the level of 4 clusters (Figures 4 & 5). All locations that fall into cluster #1 are in watersheds in the Idaho Batholith formation. All locations from the Challis Volcanic Formation and the Yellow Jacket Formation fall into clusters with a lower degree of embeddedness. This distinct separation suggests that there are geologic differences among watersheds in the South Fork Drainage that influence the degree of embeddedness.

Table 9. Sampling Location Codes and Selected Stream and Watershed Characteristics. Depth and velocity measurements are the mean values of the sample locations. B represents watersheds in the Batholith Geology; C- Challis Volcanic; Y- Yellow Jacket.

SITE NUMBER	LOCATION	STREAM ORDER	Geo. TYPE	MEAN DEPTH (cm)	MEAN VELOCITY (m/s)
1	Three Mile Creek	4	B	20	.52
2	Fourmile Creek	5	B	18	.38
5	Buckhorn Creek	5	B	35	.55
6	Blackmare Creek	4	B	25	.53
7	Cow Creek	4	B	24	.50
8	East Fork below Sugar Creek	6	B	26	.52
9	East Fork above Vibika CreeK	6	C	37	.42
10	Fitsum Creek	5	B	31	.48
11	Grouse Creek	5	B	18	.44
12	Lick Creek	5	B	24	.45
13	Monumental Creek above Mule Creek	6	C	16	.33
14	Monumental Creek below Mule Creek	6	C	14	.37
15	Profile Creek	5	Y/B	25	.45
16	Quartz Creek	5	C	28	.39
17	Secesh below Zena Creek	6	B	31	.39
18	Glory Hole	6	B	30	.67
19	Sugar Creek below W. End	4	C	22	.65
20	Sugar Creek above W. End	4	C	21	.64
21	Tamarack Creek	5	Y	23	.48
22	W. F. Monumental	5	C	20	.42
23	Zena Creek	4	B	19	.54

Figure 4. **Classification of Sampling Locations using Cluster Analysis.** Sampling locations were grouped according to the free matrix and embeddedness measurements. Highly embedded groups are toward the top of the diagram and the least embedded groups are toward the bottom. Dendrogram scale is approximate. B represents watersheds in the Batholith Geology; C- Challis Volcanic; Y- Yellow Jacket.

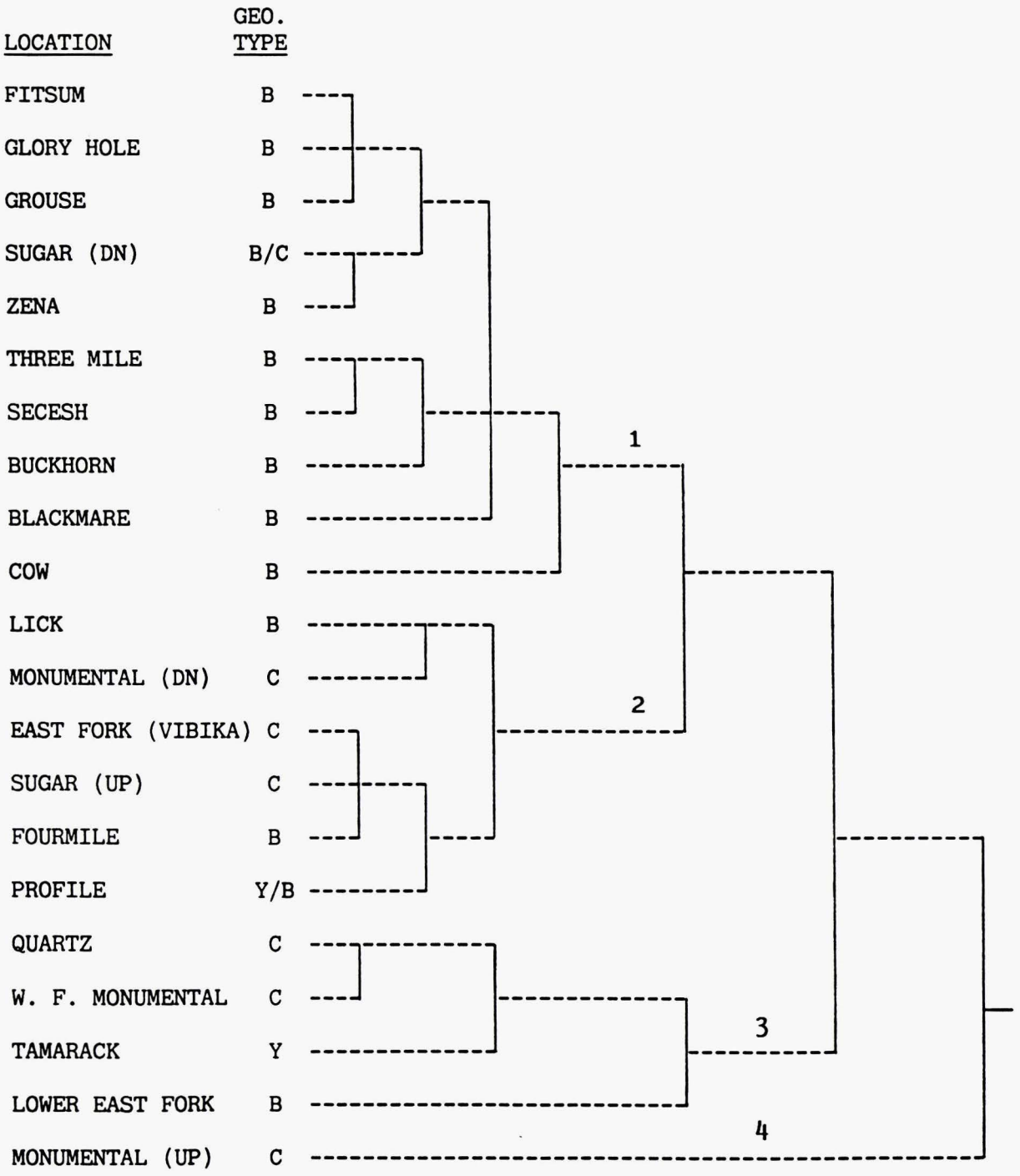
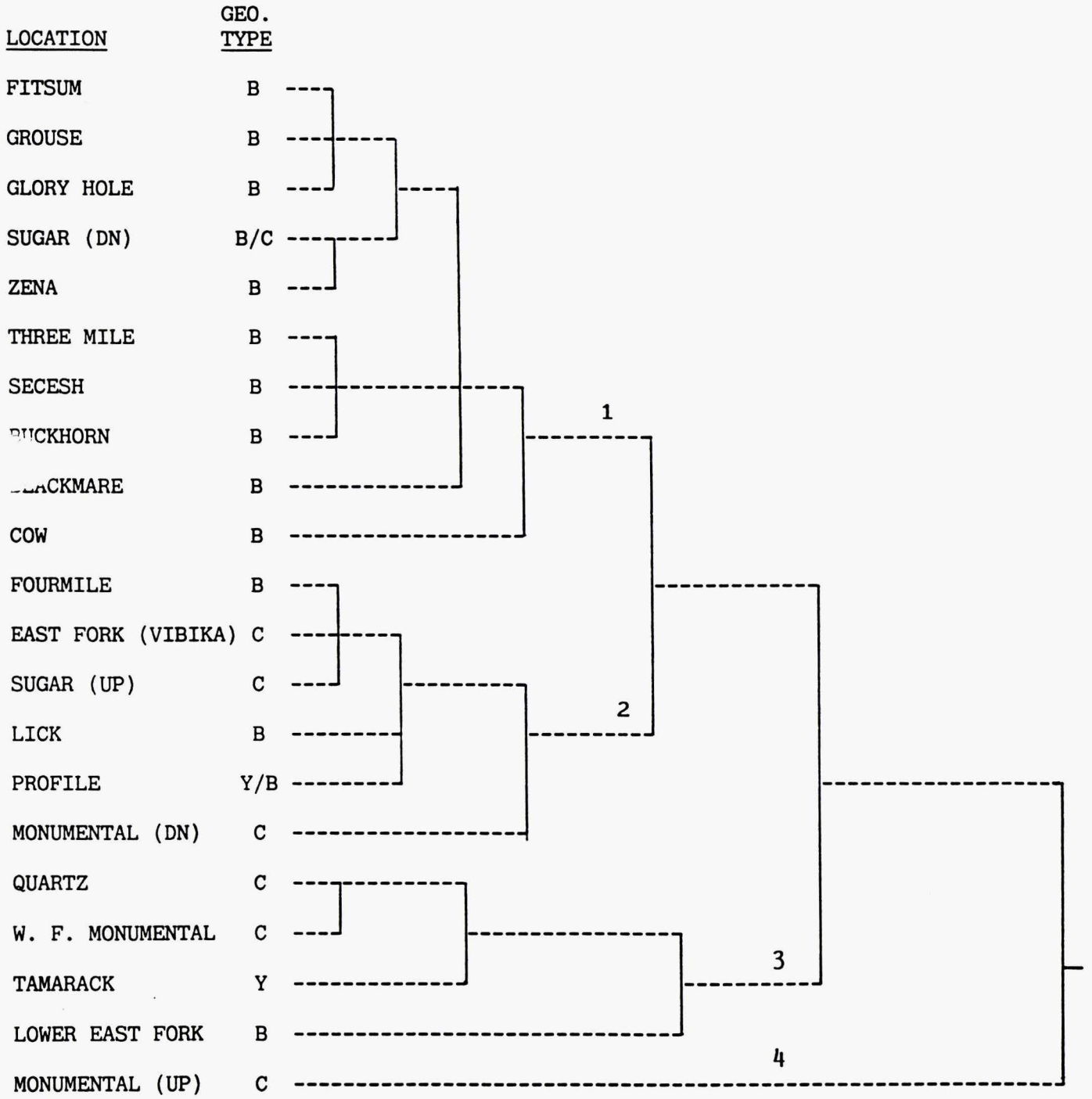


Figure 5. **Classification of Sampling Locations using Cluster Analysis.** Sampling locations were grouped according to three variables; stream order, free matrix and embeddedness measurements. Highly embedded groups are toward the top of the diagram and the least embedded groups are toward the bottom. Dendrogram scale is approximate. B represents watersheds in the Batholith Geology; C- Challis Volcanic; Y- Yellow Jacket.



The exceptions in this analysis add insight to the data. Three sites from the batholith fall into clusters of low or moderate embeddedness - Fourmile Creek, Lick Creek and the Lower East Fork. Fourmile Creek is an undeveloped site used as a control by Burns (1984), and Lick Creek is partially developed. The Lower East Fork site is in an area where the channel is cut into bedrock in places, with swift current, and a fairly steep gradient; not typical of other sampling locations. These differences in the locations were probably sufficient to separate these sites. The most distinct separation is Monumental Creek above Mule Creek, which is clearly different from all other sites. The effect of Roosevelt Lake as a sediment trap is apparent.

The significance of the cluster analysis is that we may be able to develop a means of identifying stream degradation by stratifying the samples, and analyzing group membership. There has been difficulty in associating embeddedness measurements with specific activities, or distinguishing degraded sites from sites that may naturally have a relatively high degree of embeddedness. Cluster analysis may provide additional information to address these problems.

Influence of Physical Differences in Stream Channels on Embeddedness

Free Matrix measurements from 1988 were examined with respect to stream depth, current velocity, and stream order. Each of these characteristics are associated to some degree with the amount of energy carried by the stream in a given location. Since hydraulic energy influences particle size distribution and deposition of fine sediments, embeddedness might vary with these characteristics.

Scatter plots of free matrix particles vs depth, and free matrix particles vs velocity show (Figs. 6 through 11) no significant regressions. Plots of high, moderate and low embeddedness locations are compared in the figures. A general trend is apparent. There is very little association of free matrix particles with depth, although the scatter of points tends to move upward from the low embeddedness group to the high embeddedness group (Figure 6, 7 & 8). The pooled within-group correlation for depth and free matrix particles is -0.079. Free matrix particles tend to increase with increasing velocity (Figure 9, 10, & 11). The scatter of points also tends to move upward from the low embeddedness group to the high embeddedness group. The pooled within-group correlation for velocity and free matrix particles is -0.253.

The relationship of depth and velocity with embeddedness measurements is inconclusive. Since the samples are collected at low flow conditions, the hydraulics may not reflect high flow conditions which influence particle size distribution at a particular location. Additionally, since the majority of sampling sites were highly embedded, the results may be biased.

Stream Order

Changes in free matrix particles, embeddedness, depth and velocity vary with stream order in a discernible pattern. The range of values for all four variables increased with increasing stream order. The average depth of sampling locations also increased with stream order (Figure 12), while the average velocity decreased (Figure 13). Embeddedness and free matrix

particles showed similar trends. The number of free matrix particles increases sharply with stream order (Figure 14), while embeddedness decreases in a less distinct fashion (Figure 15).

In view of these empirical observations, it is apparent that embeddedness measurements reflect not only the degree of land disturbance, but certain watershed and stream characteristics as well. Additionally, year-to-year variation in flushing flows and summer thundershowers probably strongly influence particle embeddedness. These factors have hindered interpretation of monitoring data such that only general long-term trends are discernible. For example, in Monumental Creek below Roosevelt Lake, a proportional change of 100% in fine sediments in any given year is well within the normal range of variation.

It would be advantageous to develop a stratified sampling approach to help reduce some of these confounding variables. It is clear that portions of the South Fork drainage lying within the Batholith tend to have more fine sediment than portions of the drainage located in the Challis or Yellow Jacket formations. Embeddedness also decreases with stream order. Given these two trends, the relative degree of degradation for any given embeddedness value differs by stream order and geologic type. Further monitoring should be designed to refine this issue.

Figure 6. **Free Matrix Particles vs Depth - Locations with Low Embeddedness.** The scattergram represents the percentage of free matrix particles in individual hoops and the depth of the hoop. The numbers in the figure correspond to the sample location numbers in Table 9.

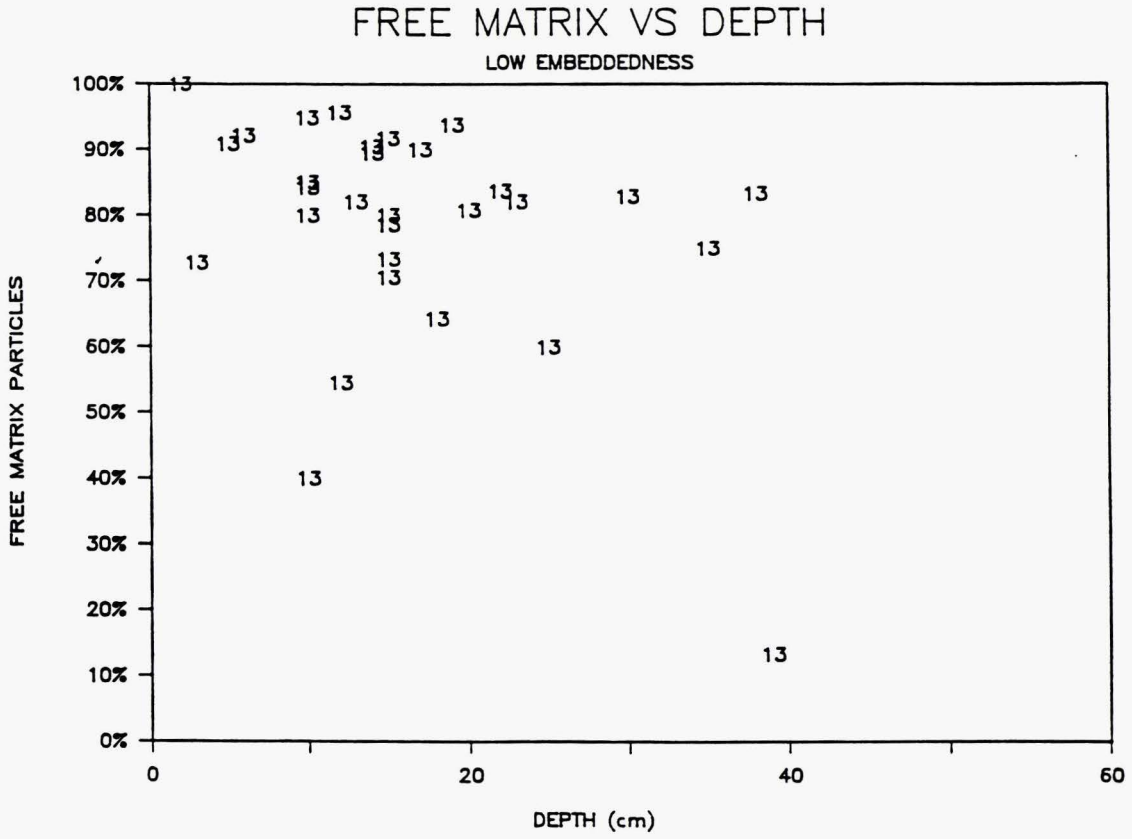


Figure 7. **Free Matrix Particles vs Depth - Locations with Moderate Embeddedness.** The scattergram represents the percentage of free matrix particles in individual hoops and the depth of the hoop. The numbers in the figure correspond to the sample location numbers in Table 9.

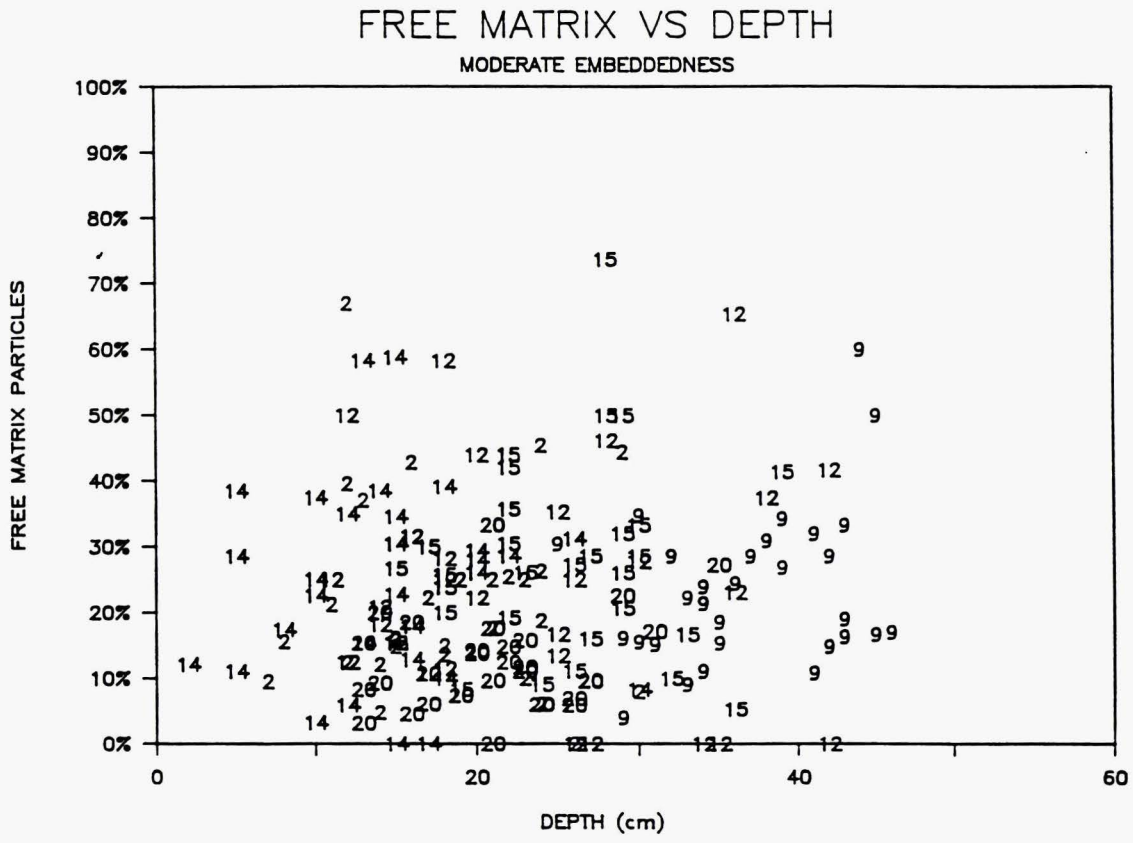


Figure 8. **Free Matrix Particles vs Depth - Locations with High Embeddedness.** The scattergram represents the percentage of free matrix particles in individual hoops and the depth of the hoop. The numbers in the figure correspond to the sample location numbers in Table 9.

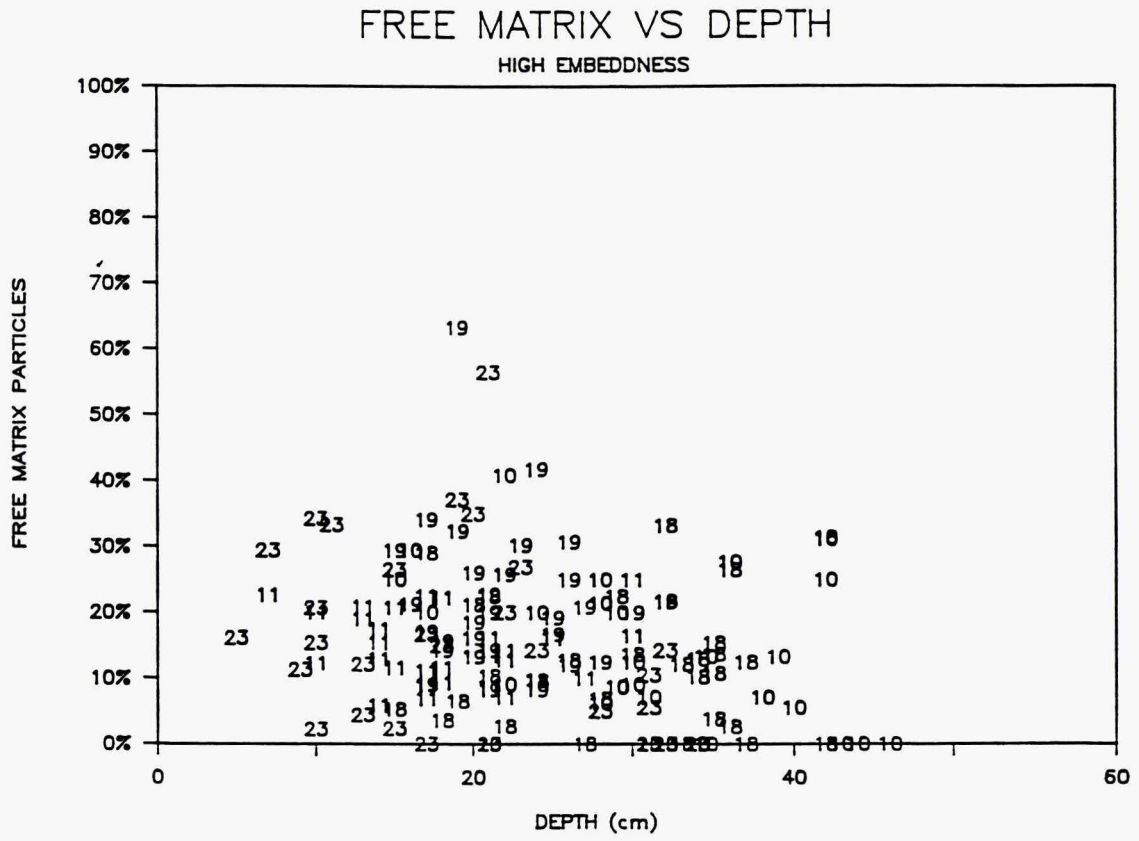


Figure 9. **Free Matrix Particles vs Velocity - Locations with Low Embeddedness.** The scattergram represents the percentage of free matrix particles in individual hoops and the surface velocity across the diameter of the hoop. The numbers in the figure correspond to the sample location numbers in Table 9.

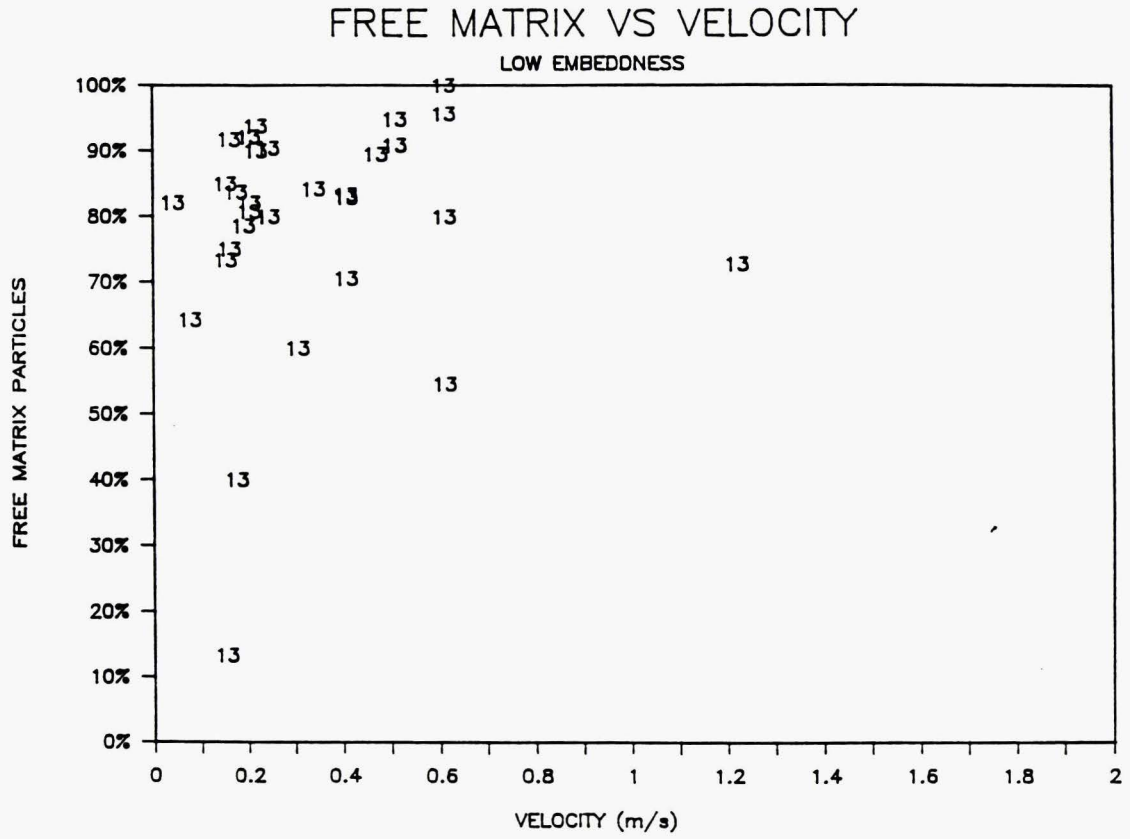


Figure 10. **Free Matrix Particles vs Velocity - Locations with Moderate Embeddedness.** The scattergram represents the percentage of free matrix particles in individual hoops and the surface velocity across the diameter of the hoop. The numbers in the figure correspond to the sample location numbers in Table 9.

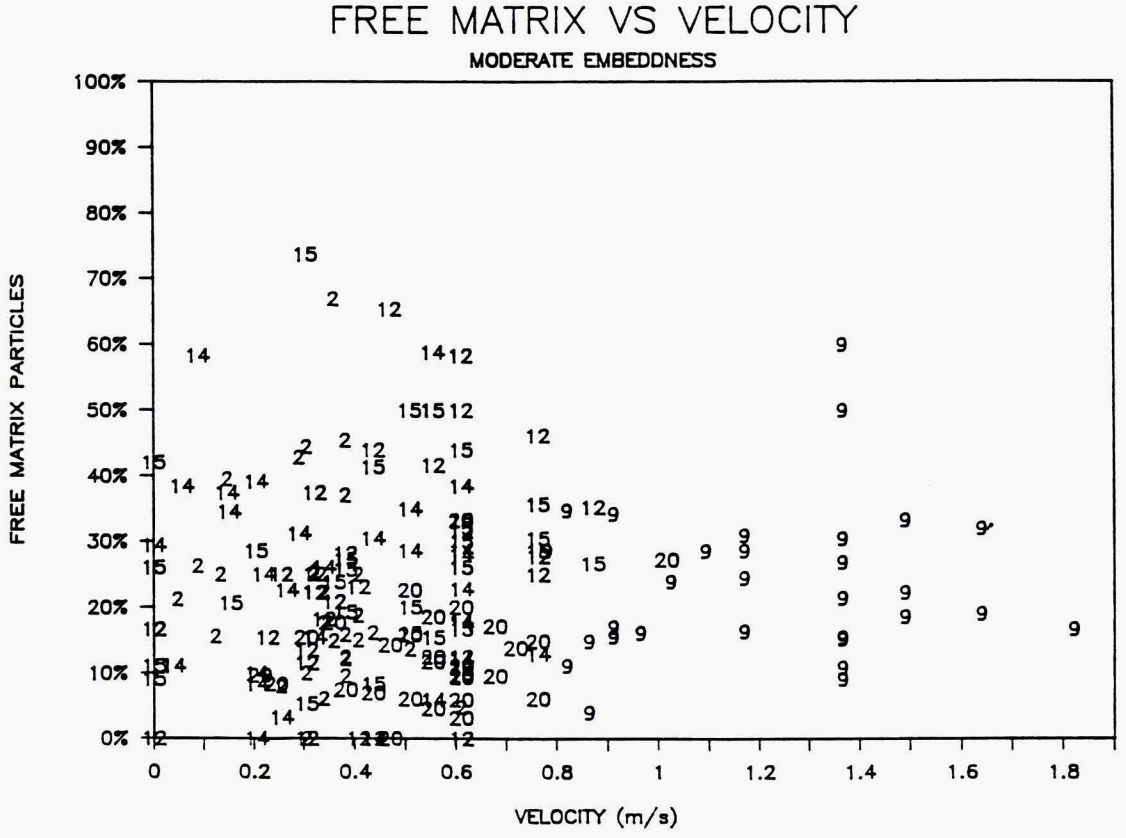


Figure 11. **Free Matrix Particles vs Velocity - Locations with High Embeddedness.** The scattergram represents the percentage of free matrix particles in individual hoops and the surface velocity across the diameter of the hoop. The numbers in the figure correspond to the sample location numbers in Table 9.

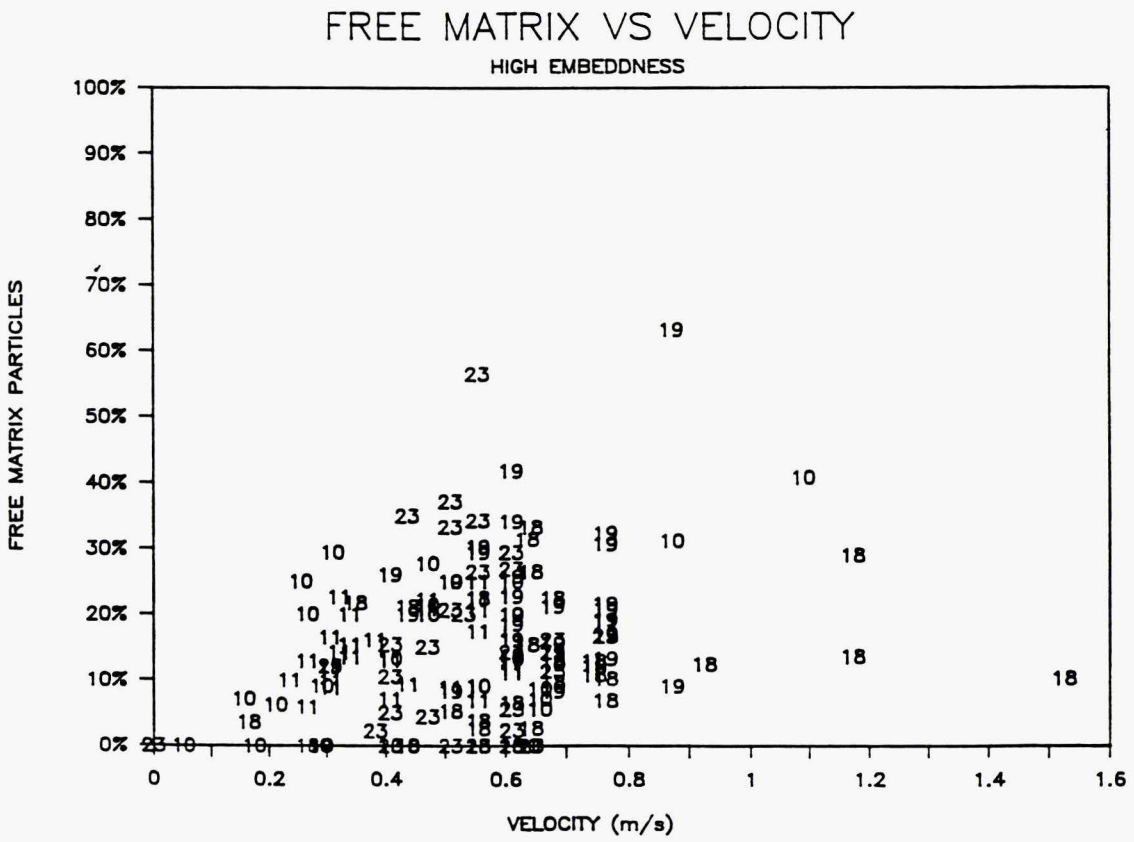


Figure 12. **Relationship of Sampling Depth and Stream Order.** The average depth and the range of depths where samples were taken increased with stream order.

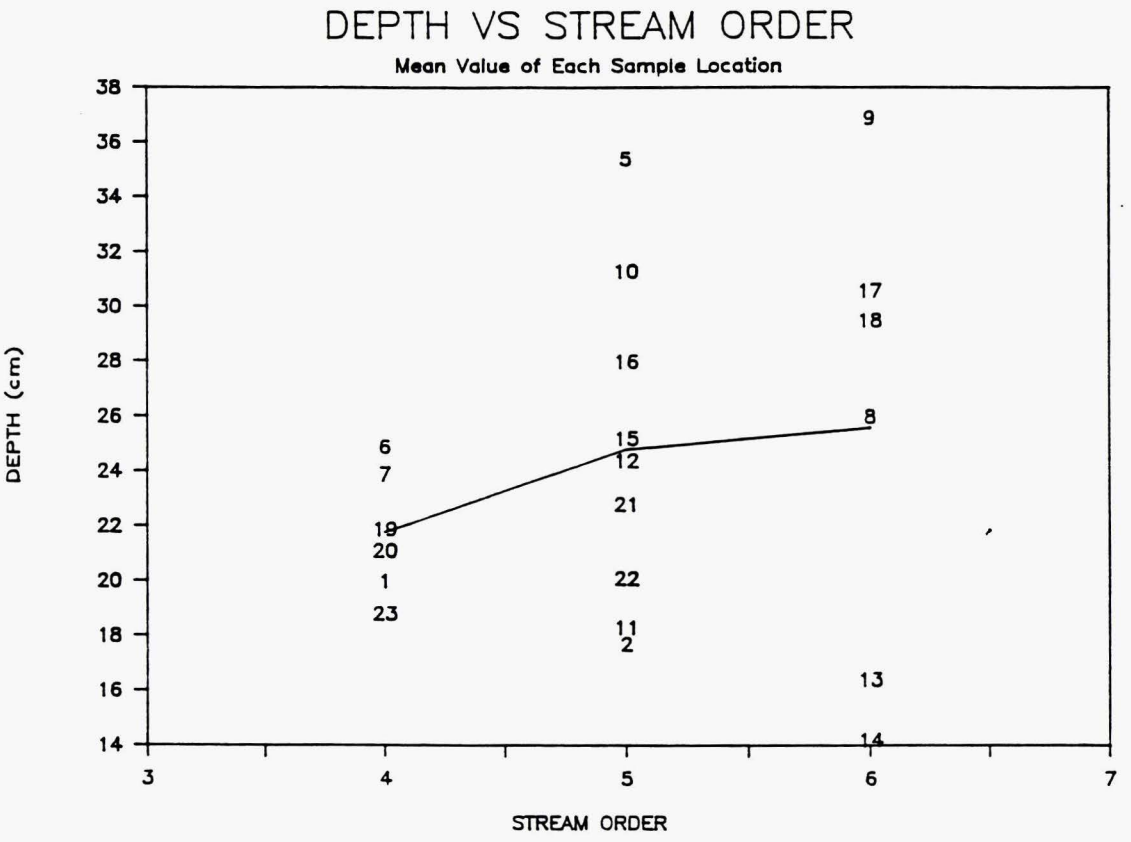


Figure 13. **Relationship of Velocity and Stream Order.** The average velocity where samples were taken decreased with stream order and the velocity range increased.

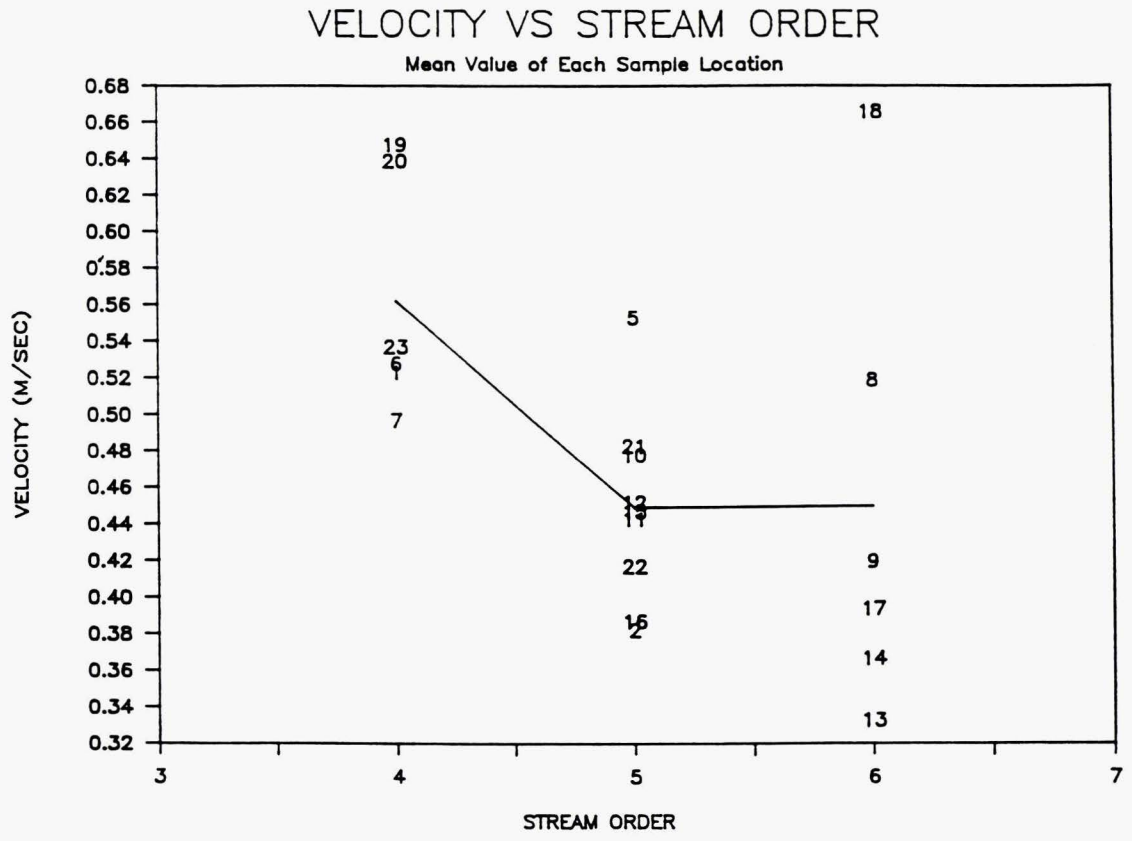


Figure 14. **Relationship of Free Matrix Measurements and Stream Order.** There is a distinct trend of an increasing range of measurements and increasing mean free matrix value with increasing stream order for the locations sampled in 1988. The pooled within groups correlation between stream order and free matrix particles is 0.27. This relationship should be regarded with caution since the sampling locations were not chosen at random.

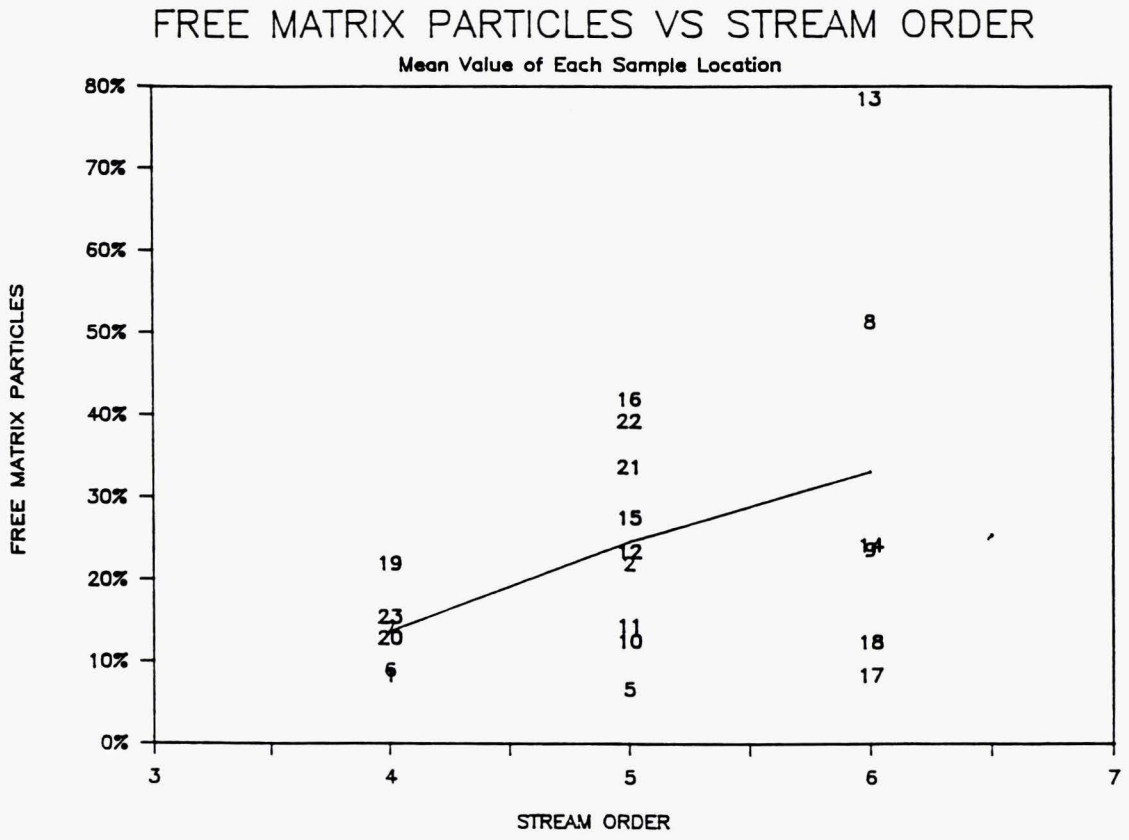
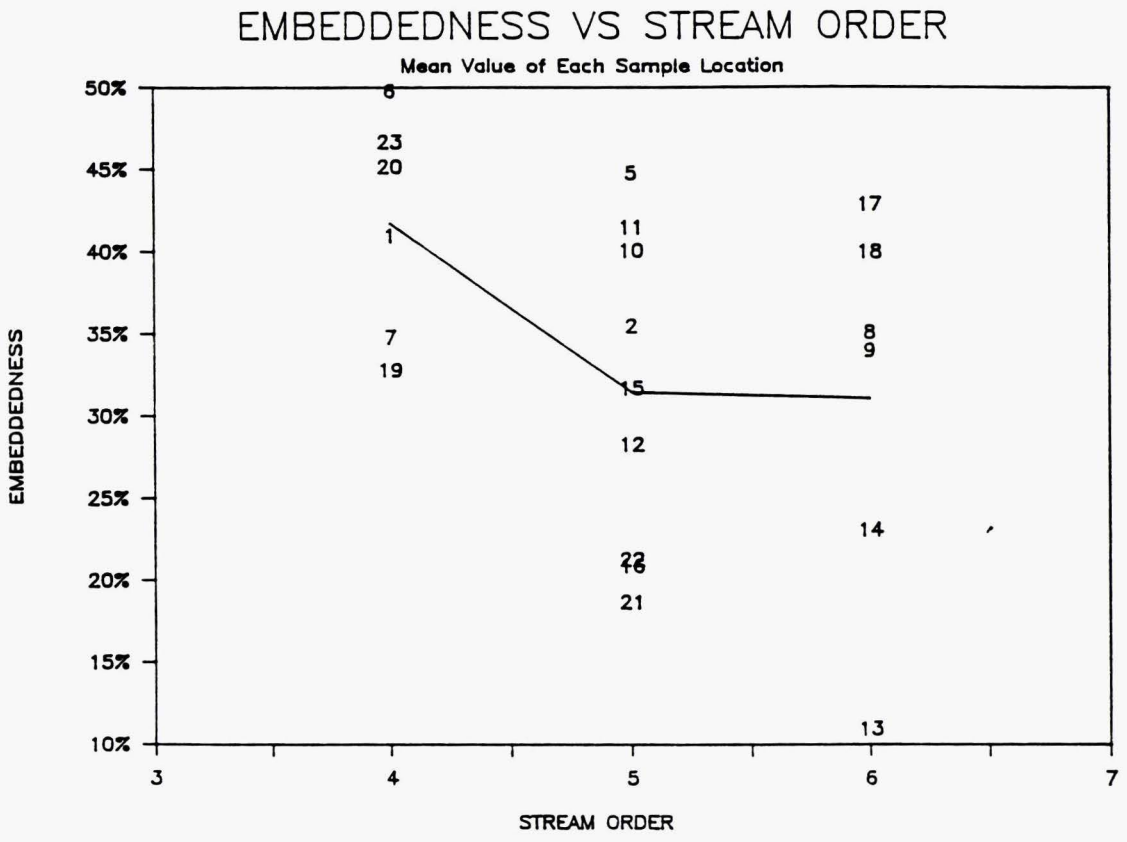


Figure 15. **Relationship of Particle Embeddedness and Stream Order.** There is a distinct trend of an increasing range of measurements and decreasing mean embeddedness with increasing stream order for the locations sampled in 1988. The pooled within groups correlation between stream order and free matrix particles is -0.27. This relationship should be regarded with caution since the sampling locations were not chosen at random.



General Observations

Several general observations were made by the authors during the course of the survey and subsequent analyses. The following is a brief summary of some key considerations:

1.) Stream energies are apparently generally sufficient to cleanse streams of severe emdeddedness, provided that major sources of fine material are absent. This is evident in the data and observations on the two mining areas. If energies were insufficient to break up the armor layer, then none of the heavily embedded locations would have exhibited cleansing.

2.) Multiple controls are mandatory to account for events such as the Blackmare storm.

3.) At least five years of consecutive data are needed to evaluate time trends in embeddedness, because of the year to year variability in data from individual locations. Year to year variability is at least as great as reported by Corley and Newberry (1982) for core sampled substrate characteristics. This kind of variability should be expected because of the relationship between core sample results and embeddedness (Burns, 1984).

4.) In order to more conclusively demonstrate cause and effect relationships between erosion sources and embeddedness, data should be collected prior to implementing land disturbances. Data presented in this report demonstrate that in the absence of obvious erosion, streams can cleanse themselves. However, it is not absolutely certain how much erosion results in a specific high level of embeddedness, because of a lack of data collection prior to some land disturbances.

5.) Stratification of samples by stream order or other size characteristics and watershed geology will help to reduce some of the overall variability in monitoring data. Variables such as stream reach gradient and channel cross-sectional area should also be recorded at each location.

6.) Multiple sampling techniques should be used when possible to account for the particular bias of each technique. However, attempts should be made to maintain continuity in the sampling techniques used in each location so that comparisons can be made between different years.

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Procedure for Embeddedness Sampling

- Go to the tail-out of a pool or run, face upstream and toss the hoop into a run area. Use the following criteria to be sure the conditions are appropriate for embeddedness measurements.

> Water velocity: float time across the hoop diameter must be between 0.9 - 2.5 seconds.
>
> Water depth: water must be between 15 cm - 45 cm deep. Do not sample in back water or eddys caused by pools or large boulders.
>
> Particle size: looking for particle sizes between 4.5 cm - 30 cm at the greatest diameter. Reject sites where all particles in hoop are <4.5 cm or >30 cm. In sample hoop, reject those few particles that are <4.5 cm or >30 cm. (It is possible to get measurements perpendicular to sediment plane that are <4.5 cm, these are acceptable and should be recorded).

- General comments on sampling techniques:

- When taking flow measurements, stand upstream and to the side so as not to effect the velocity. Imagine tangent lines to the hoop, perpendicular to flow and count float seconds at that imaginary line (not at side edge of the hoop). Always take at least 3 velocity measurements at each site.

- If the hoop lands on an angle, you should adjust it so that it lays fairly flat.

- After you have established that the hoop is in a good sample site: visually orient the hoop on the boundary rocks so that if you kick the hoop and displace it, you can return it to the original place.

- Visual clarity is usually best if you orient your back to the sun and stand to the side, so as not to disrupt the flow.

- Remove all loose rocks first: measure and record, or reject improper sized particles. Proceed from the downstream edge of hoop and move upstream in a back and forth pattern. Keep an eye on rocks that fall into hoop or that are exposed after prying out a large particle. These should not be counted.

- Measurements: Hold particle with the embedded side against the plexiglass sideboard and the embedded line perpendicular to ruler. Be cautious to keep the orientation of the particle true to its' orientation in the sediment. Suggest using the one eye reading method. Align your eye over the embedded line and read both measurements without turning your head. Every particle exposed to the water column and meeting the size criteria should be measured until the hoop contains only a plane of particles >30 cm and/or <4.5 cm diameter. Continue this process until you take at least 100 measurements. It will probably be necessary to throw at least 2 hoops. After 100 measurements have been taken, finish taking the rest of the measurements in the last hoop.

- Recording: Record the Stream Name, Date, Investigators, and Comments in the field. Describe basic location of the site in respect to bridges, boundaries, etc. On the data section: always record three digits and record the smallest number first (embedded) and largest number second ~~(exposed)~~.

Equipment for Embeddedness Sampling

-Chest waders (recommended) or hip boots
-Shoulder length rubber gloves
-Steel pry bar (45 cm long)
-Stop watch
-Transparent ruler (30 cm) affixed to plexiglass frame
-60 cm steel hoop
-embeddedness field forms on waterproof paper
-clip board
-pencils
-map of the area
-pack or duffle bag to carry gear
extra pencils

United States Department of Agriculture | Forest Service | Intermountain Research Station | 1221 S. Main Moscow, ID 83843

Caring for the Land and Serving People

Reply to: 4300

Date: March 15, 1988

Dave Burns
Payette National Forest
106 W. Park
McCall, ID 83638

Dear Dave:

The embeddedness sampling I did last fall was located in Smith and Cow Creeks on the north Idaho batholith. One-fourth mile sections of stream were stratified into slow (usually pool) and fast (usually riffle) moving categories. Sampling transects were located in each category. Along a transect, sampling points were one-third and two-thirds of stream width from the waters edge. Each 60 cm diameter hoop was considered a sample.

For each stream and category there was a relationship between percent embeddedness and percent free matrix particles (see attached graph). The mean and standard deviation for these variables for the combined data set are:

	% Embeddedness	% Free Matrix
Mean	34.4854	33.2517
Std. Dev.	11.5700	17.7616

This data can be used to estimate sample sizes required for various probabilities and precision levels. For example, the number of embeddedness samples required for a probability of .05 and a precision of 5 percent embeddedness can be estimated using.

$$n=\frac{t^2 s^2}{E^2}$$

where, E = precision
t = student's t at desired probability
s = standard deviation

$$n = \frac{(2)^2(11.5700)^2}{(5)^2} = 21 \text{ samples}$$

However, because of the good linear regression between percent embeddedness and percent free matrix particles, it may be desirable to concentrate on measuring percent free matrix particles to expedite sampling. The number of samples of percent free matrix required to obtain the dame level of precision in percent embeddedness must include the variance in percent free matrix particles and the variance in the regression. It can be expressed as:

$$\text{Var}(\%EMB) = S^2_{\beta_0} + S^2_{\beta_1} (\overline{\%FM})^2 + \frac{\beta_1^2 S^2_{fm}}{n}$$

Substituting this into the previous equation results in:

$$n = \frac{t^2_{\beta_1}{}^2 S^2_{fm}}{E^2 - t^2_{\beta_1}(S^2_{\beta_0} + S^2_{\beta_1}(\overline{\%FM})^2)}$$

For this data set, n=28 free matrix samples. This would require considerable less field time than 21 embeddedness samples. However, I do not suggest using only free matrix sampling. I do think that a double sampling scheme is appropriate. This requires a small number of samples where both variables are measured and a large sample where only free matrix particles are measured. Most texts on sampling show how to calculate the variance for double sampling.

Good luck,

Jack King

JACK KING
Research Hydrologist

EMBEDDEDNESS VS FREE MATRIX PARTICLES
PERCENT VS PERCENT